A	Segregated Witness 202-204 Taproot 205, 206
accounts 254	AES-128-CTR 252, 253
contract account (CA) 255 externally owned account (EOA) 254, 255	Agent 670
account state 268 balance 268 code hash 268 nonce 268 storage root 268	aggregate signatures 108 aggregation based oracles 237 Al 740 airdrop hunting 631 algocracy 44
account storage trie 268	Algorand 118
active replication 120 actuators 716	altcoin 208 providing 209
address data type 362 advanced Bitcoin addresses 163	Amazon Web Services (AWS) 233 reference link 514
Advanced Encryption Standard (AES) 71, 74 AddRoundKey 75	American National Standards Institute (ANSI) 530 Analog-to-Digital Converter (ADC) 718
DES 74 for decryption 76, 77 for encryption 76, 77 MixColumns 75 ShiftRows 75	analysis and design, consensus algorithm 122 model 122 processes 122 timing assumptions 123
state 74	Android proof 234
SubBytes 75 working 74, 75 advanced protocols, Bitcoin 202	anonymity phase 591 Anonymous Credentials (AnonCreds) 444, 447, 675
Bitcoin Cash 204	Anti-Money Laundering (AML) 22, 744
Bitcoin Gold 205 Bitcoin Unlimited 205	Apache Camel 508

app.js JavaScript file collision attack 636 creating 384-386 length extension attack 636 preimage attack 636 Application Binary Interface (ABI) 346, 729 attacks, on cryptocurrency wallets Application-Specific Integrated Circuits (ASICs) 185, 742 malware attacks 632 Man-in-the-Middle attacks 632 arbitrum 575 phishing attacks 632 architecture development method (ADM) 511 security vulnerabilities, in cryptocurrency phases 512, 513 wallet code 633 argument of knowledge 603 attacks, on hardware wallets arguments (AR) 598 malware attacks 633 Aries 444, 446, 675 Man-in-the-Middle attacks 633 reference link 446 physical tampering 633 arrays 363 supply chain attacks 633 user-level attacks 633 Artificially Intelligent Decentralized Autonomous Organizations (AIDAOs) 741 attacks, on layer 2 blockchains asset classes 683 attacks, on rollup provider 634 blockchain bridge-related vulnerabilities 634 asset tokenization 694 data availability attacks 634 associative 80 DSL bugs 635 asymmetric cryptography 80 state channels and side chain-related attacks blockchain technology 109 635 commitment schemes 110 transaction censoring 634 encoding schemes 116 attack trees 647 homomorphic encryption 109 attribute-based encryption (ABE) 593 integrated encryption scheme (IES) 83 Augur private key 80, 81 reference link 238 public key 81, 82 secret sharing 109 automatable 224 verifiable random function (VRF) 117 Automated Market Maker (AMM) 696 zero-knowledge proofs (ZKPs) 111-113 pros and cons 700 asymmetric cryptography algorithms 82 Autonomous Agents (AAs) 42, 740 discrete logarithm scheme 82 avalanche effect 57 elliptic curves algorithm 83 Aztec 576 integer factorization schemes 82 **URL 594** atomic broadcast 121 Azure atomic swaps 589 reference link 514 attacking hash functions

birthday attack 636

BIP37 193 В birthday attack 636 bad randomness 630 Bitcoin 9, 157, 158, 715 Bankers' Automated Clearing System (BACS) advanced protocols 202 688 altcoin 208 base 576 core client and associated tools 209 base58-encoding scheme 117 cryptographic keys 159 extended protocols 206 base64-encoding scheme 117 innovation 200 Basecoin in real world 197, 198 **URL 475** payments 198-200 Beacon Chain 409, 410 reference link 622 beacon node 410 Bitcoin addresses 161 consensus client 411 advanced Bitcoin addresses 163 execution client 411 typical Bitcoin addresses 161-163 features 410 **Bitcoin APIs** proof-of-stake 415-421 **URL 219** validator client 411, 412 Bitcoin blockchain 176 Beacon Chain nodes versus validator nodes 414 achieving, techniques 585 data structure 176-178 beacon client 418 fork 179, 180 beacon node 410 genesis block 178 Bech32 mechanism 203 orphan block 179 reference link 203 properties 180 Besu 444, 446 stale block 179 reference link 446 Bitcoin blockchain, techniques BFT algorithms 129 anonymous signatures 593 HotStuff 151-155 attribute-based encryption (ABE) 593 Istanbul Byzantine Fault Tolerance CoinSwap 589 (IBFT) 134-137 confidential transactions 592 Nakamoto consensus 144 Dandelion 590-592 PoW 146 homomorphic encryption 587 Practical Byzantine Fault Tolerance I2P 586 (PBFT) 129-131 Indistinguishable obfuscation (IO) 586, 587 Tendermint 137-141 Layer 2 protocols, using 594 BigchainDB 736 MimbleWimble 592 binary signing 745 mixing protocol 588, 589 binding 592 privacy managers 594 biometric passports 735 secure multiparty computation 587

Tor 586 Bitcoinj **URL 219** trusted hardware-assisted confidentiality 587 TumbleBit 590 Bitcoin Lightning 557 Zether 594 Bitcoin merchant solutions Zkledger 593 **URL 200** Bitcoin Cash (BCH) 204 Bitcoin miner 181, 182 reference link 204 mining pool 186 bitcoin-cli 210 mining systems 184 Bitcoin command-line tool, using 216 Proof of Work (PoW) 182-184 working with 214-216 tasks, performing 181, 182 Bitcoin client installation 209 Bitcoin miner, mining systems bitcoin.conf, setting up 211 ASICs 185 Bitcoin node, setting up 210 CPU mining 184 node, starting up in regtest 212-214 Field Programmable Gate Arrays (FPGAs) 185 node, starting up in testnet 211, 212 **GPU 184** source code, setting up 210 Bitcoin network 186, 187 Bitcoin command-line tool bloom filter 192, 193 using 216 client software 192 Bitcoin core client 209 protocol messages, types 187-191 bitcoin-cli 210 Bitcoin-NG 554 bitcoind 209 microblocks 554 bitcoin-qt 210 Bitcoin programming 219 download link 209 Bitcoin testnet **Bitcoin Core software** reference link 191 reference link 210 Bitcoin transactions 163, 164, 588 Bitcoin, cryptographic keys bugs 175, 176 private keys 159, 160 coinbase transactions 164, 165 public keys 160 data structure 167-169 **Bitcoin futures** elements 164 reference 158 lifecycle 165, 166 Bitcoin Gold 205 Script language 170, 171 reference link 205 Bitcoin transactions, data structure Bitcoin Improvement Proposals (BIPs) 201, 552 input (vin) 169 informational BIP 201 metadata 169 Payment 201 outputs (vout) 170 PaymentACK 201 verification 170 PaymentRequest 201 Bitcoin transactions, lifecycle process BIP 201 fees 166, 167 standard BIP 201 validation 166

Bitcoin transactions, Script language	fully private and proprietary blockchains 25
contracts 174, 175	functioning 18, 19
opcodes 171	generic elements 14-18
standard transaction scripts 171-174	high-profile successful attacks 620
Bitcoin Unlimited 205	history 8,9
reference link 205	in business 14
Bitcoin wallets 194	layer 1 blockchain 26
brain wallets 195	layer 2 blockchain 26
deterministic wallets 194	Layman's definition 11
hardware wallets 195	peer-to-peer (P2P) 11
hierarchical deterministic wallets 194	permissioned ledger 25
mobile wallets 195	private blockchains 24
non-deterministic wallets 194	public blockchain 24
online wallets 195	querying, with Geth 301
paper wallets 195	security 619-621
types 194	semi-private blockchains 24
BitDNS 715	shared ledger 24
	technical definition 11
BitPay	tokenized blockchains 25
URL 200, 219	tokenless blockchains 25
Bitswap mechanism 39	types 23
Blake hash function	updatable via consensus 12
reference link 287	blockchain, and IoT convergence
blind signatures 10, 104	benefits 719-721
reference link 105	blockchain application layer 628
blob-carrying transaction 434	DeFi attacks 631
blob transaction	smart contract vulnerabilities 628, 629
lifecycle 434	Blockchain as a Service (BaaS) 505, 513, 742
block-based DAGs 555	providers 514
blockchain 11	blockchain, as layer
and Al 740, 741	Applications layer 14
append-only 11	Consensus layer 14
architecture 12	Cryptography layer 13
as layer 12-14	Execution layer 14
benefits and features 20, 21	Network layer 13
challenges 743-745	blockchain-based IoT implementation 722
compatibility, checking for enterprise 498	electronic circuit, building 728, 729
distributed ledgers 11, 23	first node, setting up 725
emerging trends 741-743	Node.js, installing 727, 728
amarama r in 140	1400c.js, mstatting 121, 120

prerequisite hardware components 722 confidentiality 584 example 610-616 Raspberry Pi node, setting up 726, 727 Raspberry Pi, setting up 723-725 Zero-knowledge, using 594, 595 Solidity contract, developing 729-733 blockchain privacy, zero-knowledge protocols Solidity contract, running 734 cryptographic commitment 595-597 blockchain in finance, applications 685 proofs 597-601 financial crime prevention 686-688 ZK-SNARKs, building 601-607 insurance industry 685 blockchain services, Fabric 454 payment 688, 689 consensus service 454 post-trade settlement 685 distributed ledger 455 blockchain.info ledger storage 456 **URL 219** peer-to-peer protocol 455 blockchain layer 624 blockchain solution implementation strategy, establishing 498 attacks, on consensus protocols 626 attacks, on transactions 624, 625 blockchain technology chain reorganization 627 growth 1-4 double-spending 627 limitation 23 forking 627 limitations 21, 22 selfish mining attack 627 blockchain trilemma 546, 547 transaction replay attacks 625, 626 properties 546 blockchain layers blockchain, use cases 715, 716 blockchain application layer 621, 628 government 735 blockchain protocol layer 621, 624 health 738, 739 cryptography layer 621 IoT 716 hardware layer 621-623 media 739 interface layer 621, 631 blockchain, using Geth network layer 621-624 interacting, methods 301 **Blockchain Open Ledger Operating System** Blockchain wallet (BOLOS) 234 using 198 Blockchain oracle problem 235, 238 block cipher encryption function 73 blockchain oracles block ciphers 71 services 239, 240 operation 72 types 236 blockcracy 44 blockchain oracles, types block data (transactions) 455 cryptoeconomic oracles 239 block encryption modes 72 inbound oracles 236 outbound oracles 238, 239 cipher block chaining (CBC) mode 72 counter (CTR) mode 72 blockchain privacy 583 electronic code book (ECB) 72 anonymity 584

keystream generation mode 73 Byzantine node 741 message authentication mode 73 **Byzantium 281, 348** block headers 275, 455 C elements 275 block interval reduction 553 Cakeshop block.io transaction, viewing 538 **URL 219** Caliper 444, 448 block-less DAGs 555 reference link 448 block metadata 455 Capital Gains Tax (CGT) 743 block propagation 553 CAP theorem 6, 7 blocks 274, 444 availability 6 consistency 6 block size partition tolerance 6 increasing 552 carbon footprint, Bitcoin bloom filter 192, 193 reference link 147 bloXroute 551 Cardano Ouroboros 118 BLS cryptography 422 Casascius physical bitcoins 159 Bluetooth Low Energy (BLE) 40 Casper 295 Blum-Blum-Shub (BBS) 55 reference link 281 Boba Network 576 Casper the Friendly Finality Gadget (Casper-Boneh-Lynn-Shacham (BLS) 417, 422 FFG) 420, 429 aggregate signatures, reference link 108 Cello 444, 448 Boolean 361 reference link 448 boot nodes 282 central bank digital currency (CBDC) 22, 34 brain wallets 195 Centralized Exchange (CEX) 695 **Breadboard 722** versus DEX 700, 701 bridgefy 40 Centralized Finance (CeFi) 690 Brownie 352 centralized identity model 652, 653 reference link 352 centralized system 30 brute-force attack 635 versus decentralized system 33 btcd Central Limit Order Book (CLOB) 698 reference link 210 Certificate Authority (CA) 454, 458, 657 **BTC Relay** certificates 732 **URL 208** certificates, PBFT 131 bulletproofs 598 CFT algorithms 124 Byzantine Fault Tolerance (BFT) 122, 501 Paxos 124-127 Byzantine Generals problem 5 Raft 127-129

chain-based PoS 149 colored coins 206 chaincode 450, 452 command-line interface (CLI) 372 implementing 460, 461 commit chains 559 chained hashing scheme 147 commitment schemes 110, 111 chainlink commit phase 110 **URL 239** open phase 110 Pedersen commitment scheme 111 chain of blocks 11 commit phase 110 chain reorganization 627 binding property 110 Chain Virtual Machine (CVM) 17 hiding property 110 challenge-response protocols 82 committee-based PoS 150 challenges, enterprise blockchain committing peers 457 business challenges 518 CommonAccord compliance 518 **URL 228** interoperability 517 lack of standardization 517 common language for augmented contract knowledge (CLACK) 229 channels, Fabric 457 common reference string model 599 checkpointing 133 Common Vulnerability Scoring System Chicago Mercantile Exchange (CME) 157 (CVSS) 647 cipher block chaining mode (CBC mode) 73 compliance 503, 504 cipher feedback (CFB) mode 74 component requisites, private net ciphers 52 data directory 285 **Clearing House Automated Payment System** genesis file 285 (CHAPS) 688 network ID 284 clients, Fabric 457 computation oracles 237 client software 192 Computation Tree Logic (CTL) 642 Clique 531 conditional privacy 584 closure 80 confidentiality 502 CNexchange (CNEX) 480 confidential transactions 592 Cockpit 352 confusion property 71 code signing 745 consensus 119 coin 473 consensus algorithm coinjoin 588 analysis and design 122 CoinSwap 589 fundamental requirements 124 lottery-based 123 collision attack 636 traditional voting-based 123 collision resistance 56

consensus algorithm, selecting factors 155	querying, with Geth 377-380
finality 155	solc, used for generating ABI and code 376, 377
performance 156	testing, with Truffle 393-397
scalability 156	Truffle, installing and initializing 392, 393
speed 156 consensus client 411, 423	Truffle, used for deploying and interacting with 391, 392
	Web3 and Geth, used for interacting with 371,
consensus layer 298	372
consensus mechanism 643, 644	contracts, via frontends
consensus mechanism, Ethereum 279, 280	app.js JavaScript file, creating 384-386
consensus protocol 17, 18	frontend webpage, creating 387-391
consensus service 454	functions, calling 388
consensus states, IBFT	web3.js JavaScript library, installing 382, 383
committed 136	web3 object, creating 383
final committed 136	control structures, Solidity 365, 366
new round 136	Coq
prepared 136	URL 640
pre-prepared 136	Corda
round change 136	reference link 24
consortium chain type 497	Counter Financing of Terrorism (CFT) 22
Constant Function Market Makers (CFMMs) 700	counterparty 207, 208
constant mean market makers (CMMM) 698	armory_utxsvr 207
constant product market maker (CPMM) 697	counter block 207
Constant sum market makers (CSMM) 697	counter wallet 207
Constellation 524	server 207 URL 208
constructor function 358	
contest-driven decentralization 34	Counterparty coins (XCPs) 207
contract	CPU-bound PoW 146
functions, calling 388	CPU mining 184
contract account (CA) 255	Crash Fault Tolerance (CFT) 120, 122, 467
properties 255	cross link 410
contract creation transactions 258, 264	crowd wisdom-driven oracles 237, 238
contracts 174	cryptocurrency 250
compiling, with Truffle 393-397	cryptoeconomic oracles 239
deploying 372-376	cryptographic commitments 595-597
interacting with 398, 399	cryptographic hash function applications 63
interacting with, via frontends 381, 382 migrating, with Truffle 393-397	distributed hash tables 66, 67

Merkle Patricia trie 65,66 D Merkle tree 64 DAG-based chains 554 cryptographic hash mode 73 block-based DAGs 555 cryptographic primitives 54, 55 block-less DAGs 555 keyless primitives 55 types 555 symmetric key primitives 67, 68 Dagger 312 taxonomy 54 **DAI 45** cryptography 52,622 URI 45 accountability 54 Dai stable coin non-repudiation 53 URI 475 services 52-54 **DAML 521** cryptography layer reference link 522 attacking hash functions 636 key management-related vulnerabilities and Dandelion protocol 590-592 attacks 636 danksharding 432 public key cryptography, attacking 635, 636 DAO hack 643 ZKP-related attacks 637, 638 DAO legality cryptography, services reference link 48 authentication 53 DApps stats confidentiality 52 reference link 46 data origin authentication 53 dark web 744 entity authentication 53 reference link 744 integrity 52 multi-factor authentication 53 data availability 634 **Data Availability** Sampling (DAS) 433 cryptojacking 622, 633 Data Encryption Standard (DES) 71, 74 CryptoKitties 474, 480 data integrity service 56 **URL 474** data types, Solidity crypto malware 622 reference types 361, 363 CryptoNote 109 value types 361 crypto service provider, Fabric 459 decentralization 29-33 CureCoin 739 benefits 36, 37 **URL 739** contest-driven decentralization 34 curl 218 disintermediation 33 reference link 218, 303 methods 33 **URL 381** quantifying 34, 35 cyclic group 80, 93 requirements evaluating 37, 38

trends 48	derivatives 702, 703
working 42	flash loan 701, 702
decentralized applications (DApps) 44, 46, 230,	insurance 704
248, 471	lending and borrowing 704-707
criteria 46	money streaming 703
design 46-48	yield farming 703
operations 46	decentralized identifiers (DID) 665-670
Type 1 44	requirements 666
Type 2 45	decentralized identity and decentralized
Type 3 45	finance (DeFi) 49
decentralized autonomous corporation (DAC) 43	decentralized identity model 657
decentralized autonomous initial coin offering	decentralized marketplace 45
(DAICO) 478	decentralized mesh network 740
Decentralized Autonomous Organizations (DAOs) 3, 43, 241, 242, 250, 478, 692, 693	decentralized NFT marketplace URL 739
decentralized autonomous society (DAS) 44	decentralized oracle 238
decentralized consensus 31	Decentralized Organizations (DOs) 42, 43
Decentralized Exchange (DEX) 695-697 aggregator 699, 700	Decentralized Public Key Infrastructure (DPKI) 657
AMM, pros and cons 700	decentralized storage
CMMM 698	IPFS, using for deployment on 404-406
CPMM 697	decentralized system 31
CSMM 697	versus centralized system 33
order book-based DEX 698	decentralized web 48
versus CEX 700, 701	decrypted private key 253
decentralized finance (DeFi) 2, 690, 691, 674	decryption 52
benefits 707, 708	decryption key 253
identity 672-675	
layers 692, 693	Deep Crack 74
primitives 693, 694	DeFi attacks
properties 691	airdrop hunting 631
services 694	flash loan attacks 631
token, swapping 708, 709	forged NFTs 631
Uniswap liquidity pool 710-714	identity spoofing 631 MEV/BEV 631
Uniswap protocol 708	NFT DoS 631
decentralized finance (DeFi), services	sandwich attack 631
asset tokenization 694	stable coins stability/security risks 631
Decentralized Exchanges (DEX) 695-697	unlimited (scarcity-free) token generation 631

delegated PoS 150 decentralized identity model 657 federated identity model 653-657 demand-side economies of scale 198 self-sovereign identity 658 Denial of Service (DoS) attack 589, 623, 721 self-sovereign identity, components 659 deployment transactions 458 Digital Ledger Technology (DLT) 23 derivatives 702 Digital Rights Management (DRM) 20 derivative token 476 digital signatures 73, 82, 98 design principles, Hyperledger aggregate signatures 108 auditability 452 blind signature 104 deterministic transactions 452 elliptic curve digital signature algorithm identity 451 (ECDSA) 100, 101 interoperability 452 multisignatures 105, 106 modular structure 451 ring signatures 108, 109 portability 452 RSA digital signature algorithms 98 privacy and confidentiality 451 threshold signatures 106, 107 rich data queries 452 types 104 scalability 451 digital tree 65 deterministic wallets 194 digital wallet 670, 671 development environment governance frameworks 671, 672 connecting, to test networks 305 verifiable data registries 671 private network, creating 305-307 Digix gold tokens setting up 304 **URL 475** DeversiFi 576 Directed Acyclic Graph (DAG) 115, 312, 554, 602 DEVP2P wire protocol 283, 290 Directed Acyclic Graphs (DAGs) 39 Diem protocol Discovery protocol 282 reference link 154 discrete logarithm integrated encryption Differential Power Analysis (DPA) 636 scheme (DLIES) 83 difficulty time bomb 295 discrete logarithm problem, ECC 93-95 Diffie-Hellman algorithms 82 discrete logarithm scheme 82 diffusion 591 DiscV4 283 diffusion property 71 reference link 283 Digital Asset Holdings (DAH) 444 DiscV5 283 **Digital Asset Modeling Language** reference link 283 (DAML) 243-245 disintermediation 33 reference link 244 Distributed Artificial Intelligence (DAI) 740 digital identity 652 distributed consensus 18 digital identity, models Distributed Denial of Service (DDOS) 290 centralized identity model 652, 653 distributed hash table (DHT) 66, 67

Distributed Hash Tables (DHTs) 9, 38	electronic cash (e-cash) 9, 10
distributed ledgers 24, 444, 455	accountability 9
Besu 446	anonymity 10
Fabric 444	Electronic Frontier Foundation (EFF) 74
Indy 446	Electrum
Iroha 445	URL 195
Sawtooth 445	elliptic curve 83, 87
distributed system 4-6, 30, 119	point addition 88-90
CAP theorem 6, 7	point doubling 88-92
PACELC theorem 8	point multiplication 92
Distributed Validator Protocol 430	Elliptic Curve Cryptography (ECC) 87, 159, 258
Distributed Validator Technology (DVT) 429	discrete logarithm problem 93-95
distributive law 80	keys, generating with 95-97
DLS protocol 138	mathematics 87, 88
documentation and coding guidelines, Solidity	Elliptic-curve Diffie-Hellman (ECDH) 83, 525
reference link 369	Elliptic Curve Digital Signature Algorithm
Domain-Specific Languages (DSLs) 229, 635	(ECDSA) 83, 100, 160, 250, 638
domain-specific projects, Hyperledger 448	using 101
Grid 448	elliptic curve discrete logarithm problem
double and add algorithm 92	(ECDLP) 93
double-spending attack 627	Elliptic Curve Integrated Encryption Scheme (ECIES) 83, 283
DREAD model 647	reference link 283
	elliptic curves algorithm 83
Drizzle 352	Embark 352
E	
	embedded consensus 207
ECDSA digital signatures	enclave 524, 587
generating 102-104	encoding schemes 116
eclipse attack 623, 624	base58 117
EIP-155 626	base64 117
EIP155	encrypted private key 253
reference link 282	endorsing peers 457
EIP-1559 296-298	enrolment certificate authority (E-CA) 454
EIP-1559, variables	enrolment certificates (E-Certs) 454
baseFeePerGas 297	enterprise blockchain
maxFeePerGas 298	architecture 507
maxPriorityFeePerGas 298	available platforms 515-517

challenges 517 enums 363 versus public blockchain 506 ephemeral keys 67 enterprise blockchain architecture epidemic flooding 591 application layer 509 equity token offerings (ETOs) 477 governance layer 508 **ERC-20 interface** integration layer 508 functions and events 483-485 network layer 507 ERC-20 token privacy layer 508 adding, in MetaMask 493-495 protocol layer 508 building 483 security, performance, scalability, monitoring contract, deploying on Remix JavaScript virtual 509 machine 488-493 enterprise blockchain solutions Solidity contract, building 483-488 business-oriented factors 499 ERC-20 token standard 480 designing 509 reference link 480 limiting factors 500, 501 ERC-223 token standard 480 enterprise blockchain solutions, designing ERC-721 token standard 480 architecture development method (ADM) 511 Architecture development method (ADM) 512 ERC-777 token standard 480 cloud solutions 513, 514 ERC-884 token standard 480 TOGAF 510 ERC-1155 token standard 482 enterprise blockchains, requirements reference link 482 access governance 503 ERC-1400 token standard 481 better tools 506 ERC-1066 481 compliance 503, 504 ERC-1410 481 consistency 501 ERC-1594 481 ease of use 505 ERC-1643 481 integration 505 ERC-1644 481 integrity 501 ERC-1404 token standard 481 interoperability 504 reference link 481 monitoring 505 ERC-4626 token standard 482, 483 performance 502, 503 reference link 482 privacy 502 error handling constructs, Solidity secure off-chain computation 505 assert 368 **Enterprise Blockonomics 518** require 368 enterprise dApps 503 revert 368 Enterprise Ethereum Alliance (EEA) 3, 502 throw 368 **Enterprise Haskell 521** Try/Catch 368 **Enterprise Resource Planning (ERP) 499** Eth capability protocol reference link 284 enterprise solutions 498

ether 250, 729 **Ethereum Go client URL 305** Ethereum 407, 522, 598, 625 future roadmap 440 **Ethereum Homestead 264** identity 672 Ethereum improvement proposals (EIPS) 295, innovations 295 432 reference link 622 reference link 480 **URL 295** staking on 412-415 transactions 294 Ethereum, innovations Ethereum, after The Merge 408, 409 difficulty time bomb 295 Beacon Chain 409, 410 EIP-1559 296-298 dimensions 408, 409 merge and upgrades 298 P2P interface (networking) 421, 422 **Ethereum Name Service (ENS) 508 Ethereum block** Ethereum network 281 difficulty mechanism 278 DEVP2P 283 finalization 277 Discovery protocol 282, 283 processing 277, 278 main net 282 validation 276, 277 private nets 282 Ethereum blockchain 247, 248 RLPx 283 ecosystem architecture 249 sub-protocols 283 interacting, with MetaMask 321 test nets 282 programming languages 287, 344 Ethereum Virtual Machine (EVM) 241, 247, 270state transition function 267 272, 278, 344, 411 execution environment 273 Ethereum blockchain, elements 249 machine state 273, 274 accounts 254 cryptocurrency 250 Ethereum WebAssembly (ewasm) 272 Ethereum network 281 reference link 272 EVM 270-272 Ethereum yellow paper keys and addresses 250-254 reference link 248 messages 265, 266 Ethlance 44 miners 279 **URL 45** nodes 279 **European Union Agency for Network and** precompiled smart contracts 286, 287 Information Security (ENISA) 744 transactions 255 events, Solidity 366 wallets 289 **EVM** networks Ethereum blocks reference link 272 elements 274 EVMs (ZK-EVMs) 569 Ethereum Classic (ETC) 250, 625 execution client 411, 423 Ethereum environment (EOAs) 265 execution layer 298

extendable-output functions (XOFs) 61	Fabric, key concepts 452, 453
extended protocols, Bitcoin 206	APIs and CLIs 456
colored coins 206, 207	blockchain services 454
counterparty 207, 208	membership service 453, 454
external function calls 357	smart contract services 456
external functions 356	Fabric, transaction flow
externally owned account (EOA) 254, 265	steps 463, 464
properties 254, 255	failure detectors 121
External Owned Accounts (EOAs) 693	fallback functions 358
	faster consensus mechanisms 555
F	Fast Reed-Solomon IOP of Proximity (FRI) 597
Fabric 444, 452, 515	fault tolerance 120
core capabilities 453	fault-tolerant algorithms
messages 456	Byzantine fault-tolerance (BFT) 120
reference link 444	crash fault-tolerance (CFT) 120
Fabric 2.0 465	Federal Information Security Management Act (FISMA) 517
new chaincode application patterns 466, 467 new chaincode lifecycle management 465, 466	federated identity model 653-657
reference link 465	Feistel cipher 71
Fabric, applications 459	Fiat-Shamir (FS) 609
application model 462	field
chaincode implementation 460, 461	cardinality 80
Fabric, components	finite field 80
channels 457	order 80
clients 457	prime field 80
crypto service provider 459	Field Programmable Gate Arrays (FPGAs) 185,
membership service provider 458	742
nodes 457	Filament 721
peers 457	Filecoin 39
private data collections (PDCs) 458	Financial Conduct Authority (FCA) 504, 743
smart contracts 459	financial instruments
transactions 458	attributes 683
world state database 457, 458	financial markets 681
Fabric, consensus mechanism	exchanges 682
ordering 462 transaction endorsement 462	trading 681
validation and commitment 462	
validation and committelle 402	

financial markets, exchanges full-ecosystem decentralization 38 order management and routing systems 683 communication 39, 40 orders and order properties 682, 683 power, computing 40-42 trade, components 683 storage 38, 39 trade lifecycle 684, 685 fully private blockchain 25 finite field 80 function modifiers, Solidity firewalls 732 override 359 payable 358 flash loan 701, 702 pure 358 flash loan attack 631 view 358 FLP impossibility result 121 virtual 359 Fluff phase 591 functions, Solidity 355 FoldingCoin 739 constructor functions 358 **URL 739** external function calls 357 foreign exchange (forex) 474 external functions 356 forged NFTs 631 fallback functions 358 function modifiers 358 forking 627 function signature 356 forks 179, 281 function visibility specifiers 358 hard fork 180 input parameters 356 soft fork 180 internal function calls 357 temporary forks 180 internal functions 356 types 180 modifier functions 358 formal specifications 639 output parameters 357 formal verification 639, 644 syntax 356 model checking 641-643 function visibility specifiers, Solidity of smart contracts 640, 641 external 358 Frama-C internal 358 **URL 644** private 358 frontend attacks public 358 account hacking 633 fungible tokens 473 DoS attacks 633 divisible, working principle 473 malicious scripts 633 indistinguishable, working principle 473 misaligned frontend 633 interchangeable, working principle 473 frontend webpage working principle 473 creating 387-391 G Frontier 281 Fuel v1 576 Galois counter (GCM) mode 74 Galois fields 80

Ganache 348	Goerli test network 322
ganache-cli 348	Golem 45
ganache-ui 349-351	URL 45
gas 262, 263	Google RPC (gRPC) 455
gas limit field 258	GoQuorum plugins
Gasper PoS 410	reference link 542
gas price field 258	governance frameworks 671, 672
Gemini Dollar (GUSD) URL 475	government functions, blockchain border control 735-737 citizen identification 737, 738
General-Purpose I/O (GPIO) pins 722	elections 737
general-purpose programming languages (GPLs) 230	GPU 184
genesis block 178, 276	Greediest Heaviest Observed SubTree (GHOST) 279, 421, 553
genesis file 15, 285	GreenAddress 195
parameters 285	Grid 444, 448
genesis transaction 227	reference link 448
Geth account, creating 299-301	group signatures 593
account, creating 255-301	
POST requests, used for interacting with 380, 381	Н
	Hadamard Product Relation (HPR) 602 handshaking 283
381 used, for interacting with contracts 371, 372 used, for querying blockchain 301	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180
381 used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299	Hadamard Product Relation (HPR) 602 handshaking 283
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console experimenting with 310, 311	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234 trusted hardware-assisted proofs 235, 236
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console experimenting with 310, 311 Geth JSON RPC 301-304	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234 trusted hardware-assisted proofs 235, 236 hardware layer, blockchain 622, 623
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console experimenting with 310, 311 Geth JSON RPC 301-304 Geth RPC APIs	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234 trusted hardware-assisted proofs 235, 236 hardware layer, blockchain 622, 623 hardware oracles 236
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console experimenting with 310, 311 Geth JSON RPC 301-304 Geth RPC APIs reference link 304	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234 trusted hardware-assisted proofs 235, 236 hardware layer, blockchain 622, 623 hardware oracles 236 Hardware Security Module (HSM) 194, 637
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console experimenting with 310, 311 Geth JSON RPC 301-304 Geth RPC APIs reference link 304 global stabilization time (GST) 123	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234 trusted hardware-assisted proofs 235, 236 hardware layer, blockchain 622, 623 hardware oracles 236 Hardware Security Module (HSM) 194, 637 Hardware Security Modules (HSMs) 451, 505
used, for interacting with contracts 371, 372 used, for querying blockchain 301 used, for querying contracts 377-380 Geth attach 301, 302 Geth client 248, 289 configuring 299 installing 299 Geth console 301 Geth JavaScript console experimenting with 310, 311 Geth JSON RPC 301-304 Geth RPC APIs reference link 304	Hadamard Product Relation (HPR) 602 handshaking 283 hard fork 180 hardware description languages (HDLs) 185 hardware device-assisted proofs 234 Android proof 234 Ledger proof 234 trusted hardware-assisted proofs 235, 236 hardware layer, blockchain 622, 623 hardware oracles 236 Hardware Security Module (HSM) 194, 637 Hardware Security Modules (HSMs) 451, 505 hardware wallets 195

applications 63	smart contracts 450
message digest (MD) functions 57	URL 444
messages, encrypting with SHA-256 62, 63	Hyperledger Fabric blockchain
properties 56	capabilities 453
secure hash algorithms (SHAs) 57, 58	Hyperledger Indy 675
security properties 56	Hyperledger Landscape
hash pointer 19	URL 444
hexadecimal literals 363	Hyperledger project 515
hierarchical deterministic wallets 194, 195	Hyperledger Ursa 675
High-Performance Computing (HPC) 505	
Homestead 281, 348	
homomorphic encryption 109, 587, 741	IBD node 190
fully homomorphic system 109	IBFT 531
partially homomorphic system 109	Quorum network, setting up with 532
Horn solving 641	IBM 444
HotStuff 151, 152	reference link 514
chain quality 151	identity 651, 652
commit phase 153	in DeFi 672-675
decide phase 153	in Ethereum 672
linear view change 151	in Metaverse 672-675
liveness 154	in Web3 672
optimistic responsiveness 151	in world of Web3 673-675
pre-commit phase 153	Identity and Access Management Systems
prepare phase 153	(IAMs) 655
safety 154	challenges 656
HTTP REST interface	identity mixer 454
using 218, 219	Identity Provider (IDP) 655
hybrid encryption schemes 83	identity spoofing 631
Hyperledger	
APIs and SDKs 450	iExec
communication 450	URL 239
consensus 450	Immutable X 576
data store 450	impersonation attack 635
design principles 451, 452	inbound connections 421
policy services 450	inbound oracles 236
projects 444	
reference architecture 449, 450	

inbound oracles, types Intel Software Guard Extensions (Intel SGX) 445 aggregation based oracles 237 Interactive Oracle Proof (IOP) 597, 605 computation oracles 237 classes, categorizing 605 crowd wisdom-driven oracles 237, 238 interface layer, blockchain decentralized oracle 238 attacks on wallets 632, 633 hardware oracles 236 oracle attacks/oracle manipulation attacks 632 smart oracles 238 internal function calls 357 software oracles 236 internal functions 356 indistinguishable obfuscation (IO) 586, 587 **International Civil Aviation Organization** Indy 444, 446 (ICAO) 735 reference link 446 international standards organization (ISO) 3 Infrastructure as a Service (IaaS) 513 Internet of Things (IoT) 231, 716 Infura Internet Service Providers (ISPs) 39 **URL 321** interoperability 504 inheritance, Solidity 367 Inter-Planetary File System (IPFS) 39, 49 Initial Block Download (IBD) node 189 **IRL 49** Initial Coin Offering (ICO) 476, 716 Inter-Process Communication (IPC) 309 initial currency offering (ICO) 476, 477 Invertible Bloom Lookup Tables (IBLTs) 553 initial exchange offering (IEO) 477 Invisible Internet Project (I2P) 586 initialization vector (IV) 68, 253 invocation transactions 458 initial public offerings (IPOs) 476, 477 IoT, and blockchain convergence inner padding (ipad) 69 benefits 719-721 insecure key storage 637 IoT architecture 716, 717 Institute of electrical and electronics engineers application layer 718, 719 (IEEE) 3 device layer 718 integer factorization schemes 82 management layer 718 integer literals 363 network layer 718 physical object layer 718 integer overflow and underflow 628, 629 IPFS 352, 736 integers 361, 362 used, for deployment on decentralized Integrated Development Environments (IDEs) storage 404-406 318 IPv6 719 integrated encryption scheme (IES) 83 Iroha 444, 445 discrete logarithm integrated encryption scheme (DLIES) 83 reference link 445 elliptic curve integrated encryption scheme Isabelle (ECIES) 83 **URL 640** IntelliSense 353 Istanbul 348

Istanbul Byzantine Fault Tolerance (IBFT) 119, 120, 134-137, 430 consensus states 136 references 137 versus Practical Byzantine Fault Tolerance (PBFT) 134, 135 working 135	key reuse attack 636 keys	
	generating, with ECC 95-97	
	keystream 72	
	key stretching 195	
	Know Your Customer (KYC) 197, 503	
J	L	
JavaScript Object Notation (JSON) 302	languages, Ethereum blockchain	
JavaScript runtime environment (JSRE) 398	Low-level Lisp-like Language (LLL) 344	
Jaxx	Mutan 344	
URL 195	Serpent 344	
JSON RPC URL 302	Solidity 344	
	Vyper 344 Yul 344	
JSON RPC interface	Last in, First Out (LIFO) 170, 270	
using 217, 218 JSON Web Signature (JWS) 664	Latest Message Driven Greediest Heaviest Observed SubTree (LMD GHOST) 419,	
		Just a Bunch of Key wallets 194
K	layer 1 blockchain 26	
IX.	monolithic blockchain 26	
Kadcast 551	polylithic blockchain 26	
Keccak 61	layer 2 blockchain 26	
key derivation function (KDF) 68, 252, 253	sidechains 26	
keyed hash functions 68	Layer2 Finance 576	
key escrow attack 637	LED 722	
key establishment mechanisms 82	Ledger Blue 234	
keyless primitives 55	ledger decoupling 445	
hash functions 56, 57	Ledger Nano S 234	
random numbers 55	Ledger proof 234	
key loss or theft 637	ledger storage 456	
key management-related vulnerabilities and attacks	Legal Knowledge Interchange Format (LKIF) 225	
insecure key storage 637	length extension attack 636	
key escrow attack 637	Libbitcoin	
key loss or theft 637	URL 219	
unauthorized key sharing 637		

Libra	Machine-Readable Zone (MRZ) 735
URL 475	main net 282
libraries, Hyperledger project 446	Man-in-the-Middle (MITM) attack 635
Anonymous Credentials (AnonCreds) 447	Manticore
Aries 446	reference link 645
Transact 447 Ursa 447	mappings 364
	MasterCoin 716
libraries, Solidity 367	master key 67
LibUrsa 447	mathematical concepts 79
LibZmix 447	field 80
light clients 289	group 80
Light Emitting Diode (LED) 722	modular arithmetic 79
Light Ethereum Sub-protocol (LES) 283	sets 80
Lightweight Directory Access Protocol	mathematical puzzle 181
(LDAP) 454	Mauve Paper
Linear Temporal Logic (LTL) 642	reference link 554
literals 363	Maximal Extractable Value (MEV) 434
enums 363 hexadecimal literals 363	maximum achievable decentralization (MAD) 35
integer literals 363	maximum value 237
string literals 363	mean value 237
loan mechanism	median value 237
actors 704, 705	membership service, Fabric 453, 454
local variables 359	membership service provider (MSP) 453, 458
log replication 129	memory-bound PoW 146
log series 266	memory hard computational puzzles 147
London 348	memory pool (mempool) 205
Loopring 576	merged fee market 435
lower bound result 122	Merkelized Alternative Script Tree (MAST) 206
Low-level Lisp-like Language (LLL) 287, 344	Merkle-Damgard construction 57
low watermark 133	Merkle Patricia Tree (MPT) 65, 66, 256, 257, 572
M	nodes, types 65
М	Merkle Patricia trie (MPT) 523
mac 253	Merkle root 15, 64, 256
machine learning 740	ReceiptsRoot 257
Machine-Readable Travel Document	StateRoot 257
(MRTD) 735	TransactionsRoot 257

Merkle trees 64, 65, 256 metaverses 49 mesh communication topology 152 Metis Andromeda 576 mesh network 740 MEV/BEV 631 message authentication 53 MimbleWimble 592 message authentication codes (MACs) 53, 68 Miner Extractable Value (MEV) 436, 700 hash-based message authentication codes 69 miner node message call transactions 258, 265 functions 279 message digest (MD) functions 57 minikey 159 minimum feasible decentralization (MFD) 35 message passing 119 messages 265 mining 19 components 265, 266 mining algorithm messages, Fabric steps 182 consensus messages 456 mining pool 186 discovery messages 456 mining systems 184 synchronization messages 456 mini private key format 159 transaction messages 456 Miniscript 175 messages, PBFT 132 reference link 175 messages, Tendermint 143 mixing protocol 588, 589 pre-commit 142 mnemonic code 194 pre-vote 142 mobile wallets 195 proposal 142 model checking 641-643 MetaMask 483 modifier functions 358 accounts, importing with keystore files 328-331 custom network, adding 325-327 modulus 79 custom network, adding to connect with Remix Monero 109, 110 IDE 325-327 money streaming 703 installing 321, 322 MPC-based approach 600 Remix IDE, used for interacting contract through 336-342 Multichain blockchains used, for creating account 322-324 reference link 106 used, for deploying contract 331-335 multichain solutions 549 used, for funding account 322-324 multiparty computation (MPC) 600 used, for interacting with Ethereum Blockchain multi-party non-repudiation (MPNR) protocols 54 using, to deploy smart contract 324 Multi-Signature (M of N) 431 MetaMask wallet 289 multisignatures 105, 106 Metaverse MultiSig (Pay to MultiSig) 172 identity 672-675

Musicoin	NFT DoS 631
URL 739	node 4
Mutan 344	Node.js 347
MVC-B architecture 462	installation link 532
blockchain logic 462	URL 347
control logic 462	nodes, Fabric
data model 462	orderer nodes 457
view logic 462	node types, Merkle Patricia tree
Al	branch nodes 65
N	extension nodes 65
Nakamoto coefficient 35	leaf nodes 65
reference link 35	null nodes 65
Nakamoto consensus 120, 144	nonce 15, 68, 258
properties 146	non-deterministic wallets 194
versus traditional consensus 145	Non-Fungible Tokens (NFTs) 2, 473, 706
Namecoin 42, 715	indivisible 474
reference link 715	non-interchangeable 474
National Institute of Standards and Technology	unique 474
(NIST) 57	non-outsourceable puzzles 151
native contracts 286	not colored coins 207
Near Field Communication (NFC) 195, 588	nothing at stake problem 150, 627
network effect 198	Null data/OP_RETURN 172
network ID 284	Nxt
networking functions 428	URL 150
network layer, blockchain	
DoS attack 623	0
eclipse attack 623, 624	off-chain solutions 546, 555, 556
network spoofing 624	OMG Network 576
Sybil attack 623	Ommers validation 277
network model 138	OMNI network
network spoofing 624	URL 45
new chaincode application patterns, Fabric 2.0	on-chain scaling solutions 551
466, 467	on-chain solutions 546
new chaincode lifecycle management, Fabric 2.0 465, 466	one-way pegged sidechain 26
New Out Of Box Software (NOOBS) 723	Onion Router 586
download link 723	online wallets 195
New York Stock Exchange (NYSE) 682	

opcodes 170, 171, 288 orderer 454 reference link 289 orderer nodes 457 Open Authorization (OAuth) 654 orphan block 179 OpenBazaar Ouroboros PoS consensus mechanism, Cardano **URL 228 URL 150** Openchain outbound connections 421 reference link 106 outbound oracle 238 OpenID 655 outer padding (opad) 69 open phase 110 Out of Gas (OOG) 264 **Open Web Application Security Project** output feedback (OFB) mode 74 (OWASP) 647 Over-the-Counter (OTC) 681 OpenZeppelin toolkit 353 Oyente 644, 645 reference link 353 **URL 645** OpenZepplin 495 reference link 495 P optimal decentralization point (ODP) 35 P2P interface (networking) 421, 422 optimistic rollups 563, 564, 575 elements 421 advantages 564 P2P networks 736 disadvantages 564 PACELC theorem 8 vs ZK-rollups 573 Pacemaker 151, 154 Oracle 685 reference link 514 Pact 742 oracle-as-a-service platforms 239 PageSigner project reference link 233 oracle attacks bribing oracles 632 paper wallets 195 Denial of Service (DoS) attack 632 parallel computing 31 freeloading attacks 632 partially homomorphic encryptions (PHEs) 109 oracle censorship 632 passive replication 120 Sybil attacks 632 Password-Based Key Derivation Function 1 tampering with data sources 632 (PBKDF1) 68 oracle, is Truebit Paxos (PAX) 123-125 **URL 237 URL 475** oracle manipulation attack 629, 630 working 126, 127 preventing 630 Pay2Taproot (P2TR) 206 oracles 121, 231-233 payment channels 556 standard mechanics 232 Pay-to-Public-Key Hash (P2PKH) 172 use cases 231 Pay-to-Script Hash (P2SH) 172 order book-based DEX 698

PBFT, in Hyperledger Sawtooth	polynomial commitment schemes 596
reference link 134	Polynomial Interactive Oracle Proof
Pedersen commitments 592, 596	(PIOP) 605,606
Pedersen commitment scheme 111	post-quantum cryptography 638
reference link 111	POST requests
Peercoin	used, for interacting with Geth 380, 381
URL 150	post-trade settlement 685
peers, Fabric	PoW, alternatives 147, 148
committing peers 457	non-outsourceable puzzles 151
endorsing peers 457	Proof of Activity (PoA) 150
Peer-to-Peer (P2P) 186, 446, 507, 689, 719	Proof of stake (PoS) 148-150
protocol 455	Proof of Storage 148
pegged sidechains 26, 209	Practical Algorithm to Retrieve Information Coded in Alphanumeric (PATRICIA) 65
Peggy character 111	Practical Byzantine Fault Tolerance (PBFT) 119
permissioned ledger 25	120, 123, 129, 131, 643
Personal Package Archives (PPAs) 344	certificates 131
Petersburg 348	checkpointing protocol 133
physical unclonable functions 742	checkpointing subprotocol 129
Plasma 558, 575	commit phase 130
URL 559	Istanbul Byzantine Fault Tolerance (IBFT) 135
vs Sidechains 559	limitations 134
Platform as a Service (PaaS) 721	messages 132
point addition 88, 89	normal operation subprotocol 129
example 89, 90	prepare phase 130
point doubling 91	pre-prepare phase 129 strengths 134
example 92	versus Istanbul Byzantine Fault Tolerance
point multiplication 92	(IBFT) 134
Point of Sale (POS) terminals 200	view change protocol 132, 133
policies 454	view change subprotocol 129
Polkadot 549-551	working 130
Polkadot BABE 118	precompiled contracts 286, 287
Polygon 576	preimage attack 636
scalability solutions 576, 577	preimage resistance 56
Polygon Po 577-579	prime field 80
	privacy
polynomial commitment scheme (PCS) 605 categories 606	anonymity 502
	confidentiality 502

private blockchains 24, 553 proof of stake (PoS) 26, 46, 119, 148-150, 295, 409, 503, 553, 626 private data collections (PDCs), Fabric 458 proof-of-stake (PoS) 415-421, 430 private graph construction phase 591 **Proof of Storage 148** private key 67, 80, 159, 160, 250-252 proof of validity 233 private net 282 Proof of Work (PoW) 7, 46, 63, 119, 144, 165, components, requisites 284, 285 181, 182, 183, 184, 204, 295, 500 private network CPU-bound PoW 146 creating 305-307 memory-bound PoW 146 Geth JavaScript console, experimenting working 145 with 310, 311 Proofs of Knowledge (PoK) 447 initializing 307-310 transactions, mining 312-318 Propose Builder Separation (PBS) 435, 437 transactions, sending 312-318 proprietary blockchain 25 private transaction manager 525 protocol messages Proactive Market Maker (PMM) model 700 types 187 Probabilistic Polynomial Time (PPT) 596 provable **URL 239** Program Counter (PC) 273 pseudorandom number generators (PRNGs) 55 programming languages, Ethereum blockchain public blockchain 24 opcodes 288, 289 runtime bytecode 288 versus enterprise blockchain 506 Solidity 287, 288 public key 81, 251 projects, Hyperledger 444 public key cryptography 10, 80-82, 635 distributed ledgers 444 brute-force attack 635 domain-specific 448 impersonation attack 635 libraries 446 key reuse attack 636 tools 447 Man-in-the-Middle (MITM) attack 635 Proof of Activity (PoA) 150 side-channel attack 636 proof of authenticity 233 Public Key Infrastructure (PKI) 108, 131, 451, 657, 736 Proof of Authority (PoA) 523 public keys 67, 160 Proof of Burn (PoB) 148, 209 identifying, by prefixes 160 proof of coinage 148 public-key schemes 83 Proof of Concept (PoC) 498 puzzle-promise 590 **Proof of Deposit 148** Pycoin Proof of Elapsed Time (PoET) 445, 742 **URL 219** proof of ownership 209

proof of retrievability 148

Q	Raft 467,531		
	Raft protocol 127-129		
quadratic arithmetic program (QAP) 115	subproblems 127		
quantum key distribution (QKD) 638	Raiden 557		
quantum-safe signature schemes 638	RANDAO 426		
Quorum 515, 522	randomized algorithms 122		
access control, with permissioning 529, 530, 531	random line of nodes 591		
architecture 522	random number generators (RNGs) 55		
cryptography 525	random numbers 55		
performance 531	random strings, generating 55, 56		
pluggable architecture 542, 543	range proof 585		
pluggable consensus 531	Rank 1 Constraint System (R1CS) 115		
privacy 525-527	Raspberry Pi 722		
projects 542, 543	URL 722		
reference link 543	Raspbian		
Quorum network, setting up with IBFT 532	installation link 723		
Geth, attaching to nodes 535-537	Realitio project		
investigating, with Geth 539-542	URL 239		
private transaction, running 535 Quorum Wizard, installing 532-535	real randomness 55		
transaction, viewing in Cakeshop 538	Recursive Length Prefix (RLP) 261		
Quorum, on Azure	reference link 261		
reference link 543	Redundant Byzantine Fault Tolerance		
Quorum, on Kaleido	(RBFT) 446		
reference link 543	Reed-Solomon error correction		
Quorum privacy	using 159		
enclave decryption 528, 529	reentrancy bug 241, 629		
enclave encryption 527	reference architecture, Hyperledger 449, 450		
transaction propagation 527	reference types 361, 363		
Ouorum Wizard	arrays 363		
installing 532-535	mappings 364		
5	structs 363, 364		
R	refund balance 267		
RACE Integrity Primitives Evaluation Message	regulatory compliance 649		
Digest (RIPEMD) 58	Relying Parties (RPs) 655		
Radio-Frequency Identification (RFID) tags 718	Remix IDE 318-321, 483, 729		
Radix tree 65	custom network, connecting with 325-327		

used, for interacting contract through Ropsten 354 MetaMask 336-342 round functions 71 using, to deploy smart contract 324 **RSA 83** Remix plugin decrypting with 85-87 reference link 542 encrypting with 85-87 Remote Procedure Calls (RPCs) 190, 248 key generation process 83 replay attack 625 RSA digital signatures 98 replicated state machine (RSM) 127, 521 authenticity 99 generating 100 replication 120 non-reusability property 99 active replication 120 operation 99 passive replication 120 unforgeability property 99 state machine replication (SMR) 120 RSA puzzle solver 590 resistor 722 runtime bytecode 288 restricted private transactions 502 return on investment (ROI) 476 S reverse oracle 238 Sabre 447 reward application 277 safe curves ribbon cable connector 722 reference link 95 Ricardian contract, objects **SAFE Network** code 228 reference link 45 parameters 228 SafetyNet prose 228 reference link 234 Ricardian contracts 225-229 properties 225 salt 68 ring signatures 108, 109, 593 sandwich attack 631 Ripple labs (codius) 238 Sawtooth 444, 445, 515 reference link 445 **RLPx 283** S-boxes 71 reference link 283 Role-Based Access Control (RBAC) 503 scalability 545, 546 reference link 530 blockchain trilemma 546-548 categories 549 rollups 559, 560 improving, methods 548 data availability 560, 561 multichain solutions 549 data validity 560 off-chain solutions 555, 556 optimistic rollups 563, 564 on-chain scaling solutions 551 types 563 Polkadot 549-551 working with 561, 562 rollup solutions 559, 560

scalability, off-chain solutions Schnorr signatures 205 commit chains 559 Script 16, 170, 222 Plasma 558 Scrypt 68 Plasma chains, versus sidechains 559 second pre-image resistance 56 sidechains 557 secret key ciphers 69 state channels 556, 557 block ciphers 71 sub-chains 557 stream ciphers 70 tree chains 558 secret key cryptography 67 trusted hardware-assisted scalability 559 secret key (KEY) 73 scalability, on-chain scaling solutions Bitcoin-NG 554 secret prefix 69 block interval reduction 553 secret sharing scheme 109 block propagation 553, 554 secret suffix 69 block size, increasing 552 secure element (SE) 195 bloXroute 551 secure hash algorithms (SHAs) 57, 58 DAG-based chains 554 RIPEMD 58 faster consensus mechanisms 555 SHA-0 57 Invertible Bloom Lookup Tables 553 SHA-1 58 kadcast 551 SHA-2 58 private blockchains 553 SHA-3 58 sharding 553 SHA-3 (Keccak) 61, 62 transaction parallelization 552 SHA-256 58-60 scalability, rollup solutions Whirlpool 58 data availability 560, 561 secure multiparty computation data validity 560 (SMPC) 502, 587 example 577 security analysis tools and mechanism 638, 639 fraud proof-based classification 575-577 formal verification 639, 640 multilayer solutions 579, 580 smart contract security 644, 645 optimistic rollups 563, 564 **Security Assertion Markup Language** optimistic rollups, versus ZK-rollups 573 (SAML) 654 Polygon PoS 577-579 security, blockchain 619-621 types 563 security protocol 54 usage 561, 562 validity proof-based classification 575-577 security token offerings (STOs) 476, 477 ZK-EVM 570-573 seed 55 ZK-Rollups 564-566 Segregated Witness (SegWit) 164, 202, 552 ZK-Rollups, building technologies 566-569 improvements 202, 203 ZK-ZK-rollups 573 transactions 203, 204 scalability trilemma 440 selective disclosure 584 scalar point multiplication 92

self-destruct set 266 simulator 603 selfish mining attack 627 Single Board Computer (SBC) 722 Self-Sovereign Identity (SSI) 658 single-factor authentication 53 components 659 Single Sign On (SSO) 508, 654 decentralized identifiers 665-670 slashing 413 digital wallet 670, 671 Slither 645 verifiable credentials 659 smart contract engines 447 semi-private blockchains 24 smart contract, oracles send fail issue 628 hardware device-assisted proofs 234 separation of concerns 528 software and network-assisted proofs 233 Sepolia smart contracts 37, 42, 174, 221, 222 **URL 489** deploying 240, 241, 354 Sepolia test net deploying, with MetaMask 324 reference link 305 deploying, with Remix IDE 324 oracles 231-233 serialization 261 properties 222-224 Serpent 344 real-world application 224, 225 Seth 447 technology 242 SHA3-256 hash function 253 testing 353 SHA-3 (Keccak) 61, 62 Truffle, used for testing and deploying 399-404 SHA-256 58-60 writing 353 hash computation 59 smart contract security 644 messages, encrypting with 62 smart contract services, Fabric 456 pre-processing 58 events 456 Shapella 440 secure container 456 sharding 432-440, 553 secure registry 456 shared key cryptography 67 smart contract, technology shared ledger 24 Digital Asset Modeling Language 243-245 Solana Sealevel 242 shared memory 119 smart contract templates 229, 230 sidechains 26, 557 smart contract vulnerabilities 628 side-channel attack 636 integer underflow and overflow 629 Silk Road marketplace 593 oracle manipulation attack 629, 630 Simple Payment Verification (SPV) reentrancy 629 clients 289 send fail issue 628 nodes 192 timestamp dependency bugs 628 Simple Serialize (SSZ) 422 unguarded selfdestruct 629 simple transaction 258, 264 unprivileged write to storage 629

smart oracles 238 challenges 676, 677 Hyperledger Indy 675 SMR problem 9 initiatives 676 SMT (Satisfiability Modulo Theories) 641 other projects 676 **SNARKs** Ursa 675 types 601 SSI stack soft fork 180 four-layer model 671 software and network-assisted proofs 233 SSL stripping 635 TLS-N-based mechanism 233 stable coins stability 631 TLSNotary 233 stable tokens 474 Software Guard Extensions (SGX) 587, 742 algorithmically stable 475 software oracles 236 commodity collateralized 475 Solana Sealevel crypto collateralized 475 reference link 242 fiat collateralized 475 solc 287 stake grinding attack 627 experimenting with 345-347 stale block 179 installing 344, 345 standard transaction scripts 171 used, for generating ABI and code 376, 377 state and nonce validation 277 Solgraph 646 state channels 556 **URL 646** performing, steps 556 Solidity 287, 344, 354, 628, 736, 742 state machine replication (SMR) 6, 120 control structures 365, 366 data types 361 states, Ethereum blockchain error handling 368 account state 268 events 366 world state 268 features 354, 355 state variables 360 functions 355-359 state variables, modifiers inheritance 367 constant 361 libraries 367 immutable 361 reference link 288 state variables, Tendermint 143 variables 359 lockedRound 143 Solidity compiler 344 lockedValue 143 Solidity language 529 step 143 speed 502 validRound 143 validValue 143 sponge and squeeze construction 61 state variables, visibility scope spreading phase 591 internal 360 SSI-specific blockchain projects 675 private 360 AnonCreds 675 public 360 Aries 675

static keys 67	system model, Tendermint
status 49	network model 138
reference link 49	processes 138
Steemit 49	security and cryptography 139
URL 49	state machine replication 139
Stem phase 591	timing assumptions 139
storage root 268	Т
stream ciphers 69,71	Towns & OOF
operation 70	Taproot 205
types 70	Merkelized Alternative Script Tree (MAST) 206 Pay2Taproot (P2TR) 206
STRIDE model 647	Schnorr signatures 205
benefits 647	T-Certs 454
implementing 648	temporary forks 180
string literals 363	
structs 363, 364	Tendermint 137, 138 messages 142, 143
structured reference string (SRS) 601	properties 139
sub-chains 557	state transition 139
reference link 557	state variables 143
subnets 417	usage 140,141
substitution-permutation network (SPN) 71	Tendermint Core
subverted approach 600	URL 144
Succinct Non-Interactive Argument of	Tessera 524
Knowledge 598	test nets 282
suicide set 266	test networks
Swarm 283, 290, 291, 352, 736	connecting to 305
reference link 291	Tether
Sybil attack 144, 623	reference link 45
symbolic execution 645	Tether gold
symmetric cryptography 51, 67, 68	URL 475
symmetric-key schemes 83	The Merge 422-431
synchronization modes	clients 423
full 299	The Open Group Architecture Framework
light 299	(TOGAF)
snap 299	reference link 510
synchrony assumptions 122	The Surge
sync node 189	phases 433

thin block 205	token standards 479		
threat matrix 647	Token Taxonomy Framework (TTF) 496		
threat modeling 646, 647	reference link 496		
threshold signatures 106, 107	tools, Hyperledger project 447		
timestamp 15	Caliper 448		
timestamp dependence 628	Cello 448		
timestamp dependency bugs 628	Tor 586		
time to live (TTL) 290	total order broadcast 121		
timing assumptions, consensus algorithm	touched accounts 267		
asynchrony 123	Town Crier		
partial synchrony 123	URL 239		
synchrony 123	trade lifecycle		
TLS-N-based mechanism 233	steps 685		
TLSNotary 233	trading instruments 683		
token engineering 495	traditional consensus		
reference link 496	properties 146		
tokenization	versus Nakamoto consensus 145		
advantages 470, 471	Traditional Finance (TradFi) 690		
disadvantages 472	Transact 444, 447		
on blockchain 470	reference link 447		
process 475, 476	transaction execution 266		
tokenized blockchains 25	transaction families 445		
tokenless blockchains 25	transaction flow, Fabric		
token offerings 476-478	steps 463, 464		
decentralized autonomous initial coin	transaction manager 524, 527		
offering 478	transaction order dependence 630		
equity token offerings 477	transaction ordering dependency bug 628		
initial coin offerings 476, 477 initial exchange offerings 477	transaction parallelization 552		
security token offerings 477	transaction pools 279		
tokenomics (token economics) 495	transaction receipts 269, 270		
tokens 469	transaction replay attack 625, 626		
fungible tokens 473	transactions 16, 255, 264, 279, 458		
non-fungible tokens (NFTs) 473	components 257-260		
security tokens 475	contract creation transactions 258, 264		
stable tokens 474	message call transactions 258, 265		
taxonomy 496	simple transactions 258, 264		
types 473	transactions per second (TPS) 531, 549		

transactions, SegWit TumbleBit 590 P2SH-P2WPKH 204 phases 590 P2SH-P2WSH 204 tumbler 590 P2WPKH 203 two-phase commit (2PC) 125 P2WSH 204 two-way peg 209, 557 transaction substate 266 two-way pegged sidechain 26 transaction trie 260 tx.origin 630 transaction validation 266, 277 typical Bitcoin addresses 161, 163 transparent setups 600 U transparent SNARKs 601 Transport Layer Security (TLS) 233, 732 UK Jurisdiction Taskforce (UKJT) 224 tree chains 558 unauthorized key sharing 637 Trezor uncle block 274 **URL 195** unconditional privacy 584 Triple DES (3DES) 74 unguarded selfdestruct 629 TrueBit uniform reference string (URS) 600 **URL 239** Uniform Resource Identifier (URI) 200, 662 Truffle 351-353, 732 unrestricted private transactions 502 installing and initializing 392, 393 unsolvability results 121 **URL 351** used, for compiling contracts 393-397 Unspent Transaction Output (UTXO) 169, 203 used, for deploying with contracts 391, 392 Ursa 444, 447 used, for interacting with contracts 391, 392 reference link 447 used, for migrating contracts 393-397 **USDT** (Tether) used, for testing contracts 393-397 **URL 475** used, for testing smart contracts 399-404 used, for deploying smart contracts 399-404 V Trusted Execution Environment (TEE) 234, 445, validator node 411, 412 508,588 status 412 trusted hardware-assisted confidentiality 587 validator nodes trusted hardware-assisted proofs 235, 236 versus Beacon Chain nodes 414 trusted hardware-assisted scalability 559 validium (validia) 575 trusted model 600 Value-Added Tax (VAT) 743 trusted non-universal setup 601 value types 361 trusted universal setup 601 address 362 T-shaped cobbler 722 Boolean 361

integers 361, 362	Web3
literals 363	identity 672-675
variables, Solidity 359	used, for interacting with contracts 371, 372
global variables 359, 360	web3.js JavaScript library
local variables 359	installing 382, 383
state variables 360	web3 object
Verifiable Credentials (VCs) 659	creating 383
architecture, components 660	WebAssembly (Wasm) 272
benefits 659	Web evolution, reviewing
ecosystem 662	Web 1 49
structure 662-664	Web 2 49
verifiable presentation 665	Web 3 49
Verifiable Data Registries (VDRs) 661, 671	web layer 48
verifiable presentation (VP) 665	Weierstrass equation 87
verifiable random function (VRF) 117, 150	Whisper 283, 290, 291, 352
URL 150	reference link 290
view change protocol 132, 133	whistleblowing validator 413
virtual machine 17	whitepapers, Hyperledger
virtual mining 148	reference link 449
virtual read-only memory (virtual ROM) 271	Why3 644
Visual Studio Code 353	Wired Equivalent Privacy (WEP) 636
VMware Blockchain (VMBC) 518	Wireshark
architecture 520, 521	URL 191
components 519	witness 603
consensus protocol 519	witnet
for Ethereum 522	URL 239
reference link 521	world computer 407
VR headsets 4	World of Accountancy 227
Vyper 344	World of Law 227
14	
W	world state 268
Waffle 353	database 457,458
reference link 353	world state trie 268
Wallet Import Format (WIF) 159	X
wallets 289	
weak collision resistance 56	XOR (exclusive OR) 61

Υ	ZK-EVM 570-572		
	categories 572		
yield farming 703	reference link 573		
	types 572, 573		
YUL	Zkledger 593		
reference link 272	ZKP-related attacks		
Z Zcash 110, 113	attacks on privacy 637 digital signature vulnerabilities 637 inadequate bit security 637		
URL 21, 111	proof malleability 638		
zero-knowledge proofs (ZKPs) 111, 112, 502, 584, 597-601, 737, 741	quantum threats 637 setup vulnerabilities 638		
Ali Baba's Cave analogy 111	ZK-rollups 575		
challenge phase 113	vs optimistic rollups 573		
completeness property 111	zk-SNARK construction		
response phase 113	arithmetic circuit 115		
soundness property 111	QAP 115		
witness phase 113	R1CS 115		
zero-knowledge property 111	ZKSpace 577		
zero-knowledge range proofs (ZKRPs) 116	ZKSwap 577		
zk-SNARKs 113-116	zkSync 577		
zero-knowledge range proofs (ZKRPs) 116	ZK-ZK-rollups 573 Zooko's Triangle 42		
zero-knowledge Succinct Transparent Argument of Knowledge (zk-STARK) 113, 598			
building 601-607			
commitment 607			
evaluation 608			
evaluation proof, verifying 608, 609 limitation 115			
proof generation 115			
properties 114			
setup 607			
versus, zk-SNARKs 116			
zero-knowledge (ZK) rollups 564-566			
cons 569			
technologies, used for building 566-569			
Zether 594			

Download a free PDF copy of this book

Thanks for purchasing this book!

Do you like to read on the go but are unable to carry your print books everywhere? Is your eBook purchase not compatible with the device of your choice?

Don't worry, now with every Packt book you get a DRM-free PDF version of that book at no cost.

Read anywhere, any place, on any device. Search, copy, and paste code from your favorite technical books directly into your application.

The perks don't stop there, you can get exclusive access to discounts, newsletters, and great free content in your inbox daily

Follow these simple steps to get the benefits:

1. Scan the QR code or visit the link below



https://packt.link/free-ebook/9781803241067

- 2. Submit your proof of purchase
- 3. That's it! We'll send your free PDF and other benefits to your email directly